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TITLE: Nanoporous silica dielectric films modified by electron beam exposure and having low dielectric constant and low water content

Abstract Text (1):

Nanoporous silica dielectric films are modified by electron beam exposure after an optional hydrophobic treatment by an organic reactant. After formation of the film onto a substrate, the substrate is placed inside a large area electron beam exposure system. The resulting films are characterized by having a low dielectric constant and low water or silanol content compared to thermally cured films. Also, e-beam cured films have higher mechanical strength and better resistance to chemical solvents and oxygen plasmas compared to thermally cured films.

Brief Summary Text (9):

Thus, it would be desirable to produce a nanoporous silica film which has a dielectric constant ≤ 2.5 , which contains low levels of water and which is stable to oxygen plasma as well as to other chemical solvents used in IC fabrication. This can be accomplished in accordance with this invention, wherein nanoporous silica dielectric films are modified by electron beam exposure after an optional hydrophobic treatment by an organic reactant. The resulting films retain their nanoporous structures with reduced pore sizes, and initially have lower water content compared to thermally cured films, and hence have a dielectric constant lower than or the same as that of the thermally cured films. The resulting films have essentially no or a reduced amount of carbon and hydrogen after the electron beam process. These electron beam treated films are also not affected by oxygen plasma and chemical solvents, such as used in IC fabrication. The resistance to oxidizing plasma and chemical solvents results from the absence of methyl groups in the film as well as because of e-beam induced densification. Without the electron beam process, the oxygen plasma would react with the trimethylsilyl groups to form water. The water would raise the dielectric constant of the film and lead to high leakage current between metal lines. Although it has been previously suggested to form hydrophobic nanoporous films by treating the film with an organic surface modification reagent, the benefits of exposing such films to an electron beam were heretofore not known. Such prior art is exemplified by U.S. Pat. Nos. 5,494,858; 5,504,042; 5,523,615; and 5,470,802, as well as Ramos, et. al., "Nanoporous Silica for Dielectric Constant Less Than 2, ULSI Meeting, Boston, Mass., October 1996; Ramos, et. al., "Nanoporous Silica for ULSI Applications", 1997 Dielectrics for ULSI Multilevel Interconnection Conference (DUMIC), P. 106; and Jin, et. al., "Porous Xerogel Films as Ultra-Low Permittivity Dielectrics for ULSI Interconnect Applications", ULSI Meeting, Boston Mass., October 1996.

Detailed Description Text (26):

After formation of the nanoporous film which may or may not have been treated with the surface modifying agent, the substrate is placed inside the chamber of a large area electron beam exposure system, such as that described in U.S. Pat. No. 5,003,178 to Livesay, the disclosure of which is incorporated herein by reference. This apparatus exposes the entire substrate to an electron beam flux all at once. The electron beam exposure is done at a vacuum in the range of from about 10^{-5} to about 10^{-2} torr, and with a substrate temperature in the range of from about 25.degree. C. to about 1050.degree. C. The electron energy and doses will fall into the ranges of about 0.5 to about 30 KeV and about 500 to about 100,000 $\mu\text{C}/\text{cm}^2$, respectively. The nanoporous dielectric is subjected to an electron